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Research paper

# Growth curves and their associated weight and height factors in children from birth to 4 years old in West Azerbaijan Province, northwest Iran

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ABSTRACT

*Background:* Growth trajectory standards are important components that need to be monitored for suitable child growth. This study examined longitudinal data to identify the factors affecting growth trajectory standards of height and weight for infants.
*Methods:* This study included 566 neonates (286 boys and 280 girls) born in West Azerbaijan Province, northwest Iran, who were followed from birth to 4 years of age. The subjects' weight and height were recorded at birth, 1, 2, 4, 6, 9 months and 1, 1.5, 2, 3, and 4 years of age. In this study, the Lambda-Mu-Sigma (LMS) method was used to construct the growth curves for each measure. The linear mixed model was employed to determine the factors affecting the growth trajectory.
*Results:* The study demonstrates that the place of birth, duration of breastfeeding, and infants' gender had a significant effect on the growth trajectory. Nonetheless, other variables did not have any significant effect on growth. Growth curves for significant factors of weight and height (5th, 50th, 95th percentiles) were obtained. There was a rapid increase in the growth curve from birth to 2 years of age, which then remained relatively constant up to 4 years of age.
*Discussion:* This paper provides the first local growth trajectory standards of height and weight for infants by analyzing longitudinal measurements in West Azerbaijan province. This study determined the factors affecting the growth trend in both indices. It seems that there was a significant difference in the growth trajectories of infants in subgroups of the effective factor.


## 1. Introduction

Monitoring growth from birth is a common practice intended to detect growth failure and its association with undesirable factors. It is only then that remedial action can be utilized to prevent or reduce nutritional disorders as well as chronic and infectious diseases in childhood, mostly in the first few years of life [1,2].

Anthropometric measurements as significant indicators for predicting infants' health are the most suitable method for evaluating the nutritional and general health status of a community [3,4]. An infant's weight, height, and head circumference are considered to be the most common parameters for investigating an infant's physical growth [5].

Growth curves, an empirical model to monitor growth patterns over a period of time, are the most widely and acceptable guidelines utilized to evaluate an individual's health status [6]. This curve can be obtained by plotting the increase in size or numbers against elapsed time [7]. Growth curves are designed based on the methods in which the samples are chosen, and also on cross-sectional, longitudinal, and mixed longitudinal design [5,8]. Most growth studies are based on cross-sectional data to evaluate growth patterns. Longitudinal studies have also been used to assess the growth patterns in a few developed countries. These studies are more valuable when compared to cross-sectional studies, hence, development of the subjects over time can be considered in growth studies [9].

Over the past two decades in Iran, many studies have assessed infant growth utilizing growth curves [5,10–12], but at present no study has assessed the growth standards as a reliable measure for monitoring child growth in West Azerbaijan Province, northwest Iran.

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However, the local standards of one area may differ from those of another. Therefore, our charts can be considered for use as standard growth charts in this northwest province because the samples represent the general features of these areas. However, based on longitudinal data, few studies have attempted to investigate the influential factors on their growth trajectory [5]. Therefore, this study aimed to present the growth standards and examine the longitudinal effect of different factors on the growth trajectory measured in boys and girls 0–4 years of age, a birth cohort born in West Azerbaijan province, for weight and height, using a linear mixed model. We also compared the growth charts for weight and height by significant factors.

## 2. Materials and methods

### 2.1. Setting and subjects

A longitudinal study was conducted on the weight and height of 566 apparently healthy neonates (286 boys and 280 girls), who were randomly selected by a multistage sampling scheme forming a random sample of infants in some health centers from the nine counties (Urmia, Miandoab, Takab, Khoy, Mahabad, Bukan, Poldasht, Chaldoran, Salmas) of West Azerbaijan Province in 2012. In each county, a random sample of health centers was selected and within each health center, using a table of random numbers, we selected the sample of infants. The subjects were periodically followed from birth until the age of 4 years at the health centers.

### 2.2. Place

West Azerbaijan Province is one of the 31 provinces of Iran, located in the northwest of the country, which borders Turkey, and has 27 counties. The province covers an area of 39,487 $km^2$, or 43,660 $km^2$ including Urmia Lake, with a population of 3 million and an average annual growth rate of 1.4%. Urmia is the capital and the largest city of the province. Cold northern winds affect the province during winter and cause heavy snow [11].

### 2.3. Questionnaire data

A questionnaire on demographic information and the neonates' health status of the neonates and their parents including gender; number of children in the family; birth order; parents' age, education and occupation; age when beginning supplementary food; duration of breastfeeding; region (urban or rural); and anthropometric measurements was filled out and analyzed in this study.

### 2.4. Anthropometric measurements

Infants were visited at various target ages (birth, 1, 2, 4, 6, 9, 12, 18, 24, 36, and 48 months). Their weights and heights were measured by trained healthcare staff utilizing techniques presented by Cameron, which have been fully described elsewhere [13]. Heights were measured in centimeters in the supine position until the end of the 1st year and then in a standing position. Weight was measured to the nearest 10 g until they were 2 years of age utilizing a baby scale and from then onwards, weight was measured to the nearest 0.1 kg. The birth weights of 21 (3.7%) subjects were under 2500 g (range, 1300–2400 g).

### 2.5. Statistical analysis

The present study utilized the growth curve model to analyze the longitudinal data using a linear mixed model, excluding confounder factors, to construct the longitudinal standards for weight and height. The study used the model to verify the demographic trend variables over the ordinal variable of time. The growth curve model allows the analysis of longitudinal or repeated measures data sets where individuals may have missed measurements on one or more occasions. The growth curve model for this study is proposed as:

$$y = x\beta + zu + \varepsilon$$

This is a special case of mixed effects models. In this model, $y$ is the growth index (weight or height), $x$ is a matrix of fixed effect variables (parents' age, education, and occupation; child birth order; number of children in the family; duration of breastfeeding; gender; and region (urban or rural)). $Z$ is a matrix of random effects variables (intercept and infants' age), $\beta$ and $u$ are parameters of fixed and random effects, respectively. Parameters were estimated utilizing restricted maximum likelihood [14].

The Lambda-Mu-Sigma (LMS) method was used to construct the growth curves for the measurements of weight and height, separately for each factor. The LMS is a popular method for obtaining smooth centile curves [15]. Each centile curve is derived from three curves representing the median (M), the coefficient of variation (S), and the skewness of distribution (L). Since they change with the independent variable (age), the latter is expressed as a Box-Cox power [16]. The LMS method assumes that skew data can be normalized by utilizing a power transformation that stretches one tail of the distribution and shrinks the other tail simultaneously, thus primarily correcting the skewness. Utilizing penalized likelihood, the three curves can be fitted as cubic splines by nonlinear regression, and the extent of smoothing required can be expressed in terms of smoothing parameters or the equivalent degree of freedom [3].

General aspects of the data were analyzed using SPSS version 11.5 (SPSS Inc., Chicago, IL, USA). The growth curve model was carried out using SAS 9.2 to determine the significant factors. LMS chart Maker (professional) and Microsoft Excel software were utilized for the construction of weight and height centiles. The level of statistical significance was determined as $P < 0.05$.

## 3. Results

Among the 566 neonates who were followed from birth to 4 years of age within this study, 317 (56%) were urban dwellers. The gender distribution was almost equal, as illustrated in Table 1. The mean ± SD of the mothers' and fathers' age were 25.9 ± 5.8 and 30.7 ± 6.7 years ($P < 0.0001$), respectively. The mean duration and SD of breastfeeding was 21.2 ± 5.85 months. Almost three-quarters of mothers had a normal delivery (420 cases). One hundred fifty-three (27.1%) of the families had one child, while 213 (37.7%) had two children. Table 1 summarizes the families' demographic characteristics (Table 1).

**Table 1**
Summary of demographic characteristics of participants in the analysis ($n = 566$).

| Variable | | *N* (%) |
|---|---|---|
| Gender | Boys | 286 (50.5) |
| | Girls | 280 (49.5) |
| Region | Urban | 317 (56) |
| | Rural | 249 (44) |
| Mother's education | 0–6 | 322 (56.9) |
| | 6–12 | 201 (35.5) |
| | > 12 year | 43 (7.6) |
| Father's education | 0–6 | 235 (41.5) |
| | 6–12 | 259 (45.8) |
| | > 12 year | 72 (12.7) |

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